XI. *The Croonian Lecture. On the changes the blood undergoes in the act of coagulation. By Sir* Everard Home, *Bart. V. P. R. S.*

Read November 20, 1817.

It is not a little remarkable, that in the first Lecture of this kind, which I laid before the Society, in the year 1790, I should have endeavoured to show, that a muscular fibre was too minute an object to be seen by the human eye, even assisted by the best magnifying glasses then in use; and that in this Lecture, I shall be able, by means of the great improvements that have been made in the use of the microscope, to show that a fibre not larger in diameter than one of the globules of the blood can be demonstrated.

To the Members of this Society who have so lately seen Mr. Bauer's drawings, of the glandular apparatus peculiar to the Java swallow; of the internal membrane of the human stomach, exposing structures that were not known to exist; also of so small an object as the human ovum, in which is seen the seat of the two most important organs of the body; (drawings rendered beautiful by their simplicity and distinctness;) it will readily suggest itself, that Mr. Bauer is the person to whom I consider we are indebted for those improvements. His whole life, I may say, has been employed in investigations of a similar nature in plants, observing first the natural appearances, and then magnifying them in different

degrees, and comparing, with the nicest discrimination, what was exhibited by one magnifying power, with what was shown by that immediately above it, and, where they did not exactly correspond, employing the whole energies of his mind, with a patient labour, almost beyond what is natural, in ascertaining the cause of the deception which must in one of them have taken place. To the observations of such a man upon subjects of this nature, if we are not confidently to place a reliance, how are we to give credit to the remarks that are made by common observers?

I have said thus much as an introduction to the observations that I am going to bring forward, for the public to know, whatever opinion they may form of them, they have been the result of long and unwearied research; and have been so frequently repeated as to satisfy Mr. BAUER of their correctness.

The red globules of the blood in the human body, when enveloped in their colouring matter, appear, when measured in the microscope by the micrometer, to be $\frac{1}{1700}$ part of an inch in diameter, requiring 2,890,000 to a superficial or square inch. These globules, when deprived of their colouring matter, appear to be $\frac{1}{2000}$ part of an inch in diameter, which makes 4,000,000 of globules to a square inch. From these observations, it appears that the globules, when deprived of the colouring matter, are not quite one fifth part smaller. The colouring substance appears not to be contained in the globules, but only to envelope them: one reason for forming this opinion is, that the separation is very rapidly effected, the colouring substance flowing from all parts of the globule at the same instant, and that to retain the globules in the coloured state it is necessary that a very small quantity of blood only be

smeared as thin as possible upon the glass, in order that all moisture may instantly evaporate; they then remain of their full size and colour, perfectly spherical, as in the representation, fig. 1, Pl viii. But if a greater quantity of blood be laid upon a glass which retains moisture only half a minute, the colouring matter begins, in a few seconds, to separate and form a circle round the globule, and if the blood is diluted with water, the separation of the colouring matter is instantaneous, and the globule puts on the appearance represented in fig. 2, Pl. viii. Another reason is, the great quantity of colouring matter, it being as three to one in proportion to the globules.

The globules of the blood have neither the same size nor the same shape in all animals. Dr. YOUNG, in his introduction to Medical Literature, has described them to be of an oval form in the skate. Upon examining them in that fish, Mr. BAUER found them, while the fish was alive, of the form of an egg, but almost immediately after death, flattened. I shall, however, reserve the materials I have collected upon this subject for another communication. When the globules in the human blood lose the colouring matter, they continue floating in the serum, and are seen to have an attraction towards one another so as to coalesce, uniting themselves together. In the annexed drawing is represented their mode of union under different circumstances, surrounded by serum deeply tinged with the colouring matter. In one instance three globules are so united as to form one line; in another there is a line composed of four globules, with lateral indentations, where the union between the globules had taken place. This appearance, joined to other circumstances, renders it probable at least that the globules may be the part of the blood, out of which

the muscular fibres are principally formed, and no fibre they could form would be of smaller dimensions than the globules of which it is composed. Having expressed this opinion to Mr. BAUER, I was desirous that he should try to unravel a muscle so as to come at the ultimate fibre. Several attempts of this kind were unsuccessfully made: but in one instance, in the muscles of the thigh of a roasted chicken, a detached fibre was exposed in the microscope, which occupied upon the micrometer, the same space in every respect with the four globules which I have mentioned to have seen united, and floating in the serum of the blood before the blood had completely coagulated; the muscular fibre from the chicken could be traced to a greater length, but the indentations could not be distinguished farther on.

In prosecuting this examination of the muscular fibres, Mr. BAUER found that after being boiled or roasted, and then macerated in water, changing the water every day for a week, they were much more readily separated from each other, and that he had no difficulty in procuring single fibres similar to the one described, from the coats of the human stomach; the thigh of the sheep, and of the rabbit; and from the salmon. The appearances that different fibres put on are represented in the annexed figures, 4, 5, 6, of Plate viii.

When the fibres are macerated for a longer time, they are readily broken down into a mass of globules of the size of those in the blood, deprived of their colour. The accuracy of the appearances that have been described may be depended on; how far they will afford the slightest grounds for an opinion that the globules are the materials, and the attraction between them the means, by which the single fibres are formed, and all the

combinations produced that are met with in the structure of muscles, must require farther investigation. It is deserving of remark, that while the globules are enveloped in their colouring matter, they are not seen to run together, and coalesce with one another on the field of the microscope; it is therefore probable that the attraction, by which this effect is produced, only takes place between globules deprived of their colour.

It may not be amiss to enquire how far there is any thing in the formation of fibres in other parts of the body at all in favour of muscular fibres being composed of globules, and I shall mention that Mr. BAUER, in his examination of the substance of the brain, under the microscope, finds, that when that organ is immediately after death made the subject of examination, abundance of fibres are met with in every part of it; indeed it appears that the whole mass is a tissue of fibres, which seems to consist entirely of an accumulation of globules, whose union is of so exceedingly delicate a nature, that the slightest touch, even the mere suction in water, deranges and reduces them to that mass of globules of which the brain appears to be composed when examined with less accuracy, or under less favourable circumstances. He admits that in his first observations he was induced to believe that no such things as fibres were to be met with in the brain ,but that the whole organ consisted of a mass of these globules. He found that the globules of the brain, as well as those of pus, are exactly the same size as those of the blood when deprived of their colouring matter.

Mr. BAUER not having completed the investigation of the brain, in which he is engaged, I shall not farther anticipate

his observations upon this most important organ: as my only object in what I have already stated, is to mention, that the fibres of which it appears to be made up are composed of globules.

Upon mentioning Mr. BAUER's observations on the brain to some of my friends, I was referred to the Supplements to the 4th and 5th editions of the Encyclopædia Britannica,* in which the opinion of the brain being composed of globules is noticed. I find, upon making such reference, that there is not enough stated respecting the anatomy of the more minute parts of that organ, to supersede a farther investigation of its structure, as will appear from the following extracts.

"It (the brain) has been subjected to very minute microscopical observations by PROCHASKA.† When he took a small portion of it, either from the brain proper or the cerebellum, and spread it on a thin plate of glass, so that it became pellucid, and then examined it with a powerful microscope, he found that it resembled a sort of pulp, consisting of innumerable globules, or particles of a roundish form. A little water added to this pulp, divided it into a number of flocculi; but he observed that each flocculus was still composed of a number of globules. He very rarely found one globule by itself, or even two, floating in water, apart from the rest. Maceration in water, even for three months, was insufficient to separate them from each other. He concluded, therefore, that they were united by means of a very delicate and pellucid cellular substance. The globules, he observed, were not all of the

* Vol. 1, part 2, page 260, No. 64 and No. 65.

† Oper. Min. Pars. I. p. 342.

same size; but varied a little in dimension, even in the same part of the brain. In general, however, he found them, both in the brain proper and in the cerebellum, to be more than eight times smaller than a globule of the blood. The most powerful microscopes did not enable him to discover any thing satisfactory respecting their structure."

" These observations have, within these few years, been prosecuted on a much more extensive scale, by JOSEPH and CHARLES WENZEL.* They have uniformly found, that the white nervous matter seemed as if entirely composed of extremely small globules or corpuscules of a roundish form, putting on the appearance of little cells, filled with a proper medullary substance. No estimate is given of the dimensions of the globules, but they describe them as being exceedingly minute, and as being all pretty nearly of the same size. They seemed to adhere very closely to each other, without any apparent connecting medium. The globular appearance continued distinctly perceptible in portions of the substance, which had been long exposed to the action of rectified spirit of wine and muriatic acid; nor was it even destroyed by steeping the matter in alcohol, and then drying it."

The statements contained in both of these extracts confirm, in the most satisfactory manner, Mr. BAUER's observations, although in many respects, they are deficient in point of accuracy.

Having laid before the Society all I have to offer, respecting the appearances of the globules of the blood from which the colouring matter had been discharged, I shall endeavour to explain in what manner blood, in the act of coagulation,

* De Penitior. Struct. Cereb. p. 24.

acquires that texture, which fits it, when extravasated in living animals, to open a communication with the general circulation, and by that means become a part of the solids of the animal.

It has ever been a desideratum to ascertain in what manner blood after it had coagulated, and remained at rest in different parts of a living animal, is rendered vascular. The fact itself has long been known to every enquirer into the operations of the animal economy, and several theories have been formed to explain it. Mr. HUNTER, who perhaps understood the appearances such coagula put on, when injected from the neighbouring vessels, better than any other physiologist, was unable to trace a direct continuation of ramifying branches from the circumference of the living parts to the centre of the coagulum, and therefore referred it to a principle of life existing in the blood, which principle was consequently inherent in the coagulum, and formed a series of vessels, pervading every part of it, which opened for themselves communications with the surrounding vessels. Since Mr. HUNTER's time, no more satisfactory opinion has been advanced for the explanation of this curious phenomenon. I confess that my own attention has not, for the last twenty years, been called to this enquiry, although before that time, while I was assisting Mr. HUNTER in the prosecution of his pursuits, I gave considerable attention to it, but remained unsatisfied with all the explanations that had been given.

My attention was, however, again called to this subject last summer, by different conversations I had with Mr. BAUER, in which he told me, that to illustrate the germination and vegeta-

tion of wheat, introductory to his illustrations of the diseases in corn, he sowed a quantity of wheat, and afterwards took up every day some grains, or plants, for examination, till the ears were ripe. In his close attention to the changes that took place, he was very much struck with the rapid increase of the tubular hair of the root of a young plant of wheat, in its earliest stage of vegetation: and fixing his whole attention upon that part of the plant, he observed small pustules of a slimy substance arising under the epidermis, on the surface of the young root; and, in a few seconds, a small bubble of gas burst from the root into the slimy matter, which it extended in a moment to the length the hair was to acquire; and the slimy matter, surrounding the gas, immediately coagulated, and formed a canal. He repeated his observations on another plant, whose pubescence consisted of a jointed hair, and observed the same effect take place; a bubble issued from the young stalk, and extended the slimy mucus to a short distance, forming the first joint, which immediately coagulated and became transparent, and at its extremity a new pustule of the same slimy mucus accumulated, into which, in a short time, the gas from the first joint rushed; and thus, in a moment, a second joint was formed: in the same manner he observed the formation of the hairs of ten or twelve joints to take place.

These observations, so curious in themselves, and which explain, in so simple and satisfactory a manner, one of the modes in which tubes are formed in vegetables, and an addition is made to the plant, made so strong an impression on my mind, and so entirely engrossed my attention, that I did

not allow Mr. BAUER to rest, till he gave me his assistance in instituting experiments, to ascertain whether any thing similar takes place in animal bodies.

The first object of our enquiry was to know, whether any gas is to be found in the blood while circulating in the vessels, and under what circumstances it is separated from it. That the blood, whilst circulating in the arteries and veins, holds a considerable quantity of gas in solution, is proved by the following experiments, made at my request, by Professor BRANDE. Blood was drawn from a vein in the arm, and whilst yet warm was placed under the receiver of an air pump; during the exhaustion of the receiver, there was a considerable escape of gas from the blood, so that it had the appearance of effervescing, and soon depressed the quicksilver in the gage of the pump. He afterwards ascertained that this gas is carbonic acid gas, is met with in the same proportions in arterial and venal blood, and two cubic inches were extricated from every ounce of blood.*

That a considerable portion of this carbonic acid gas, is extricated from the blood during the spontaneous coagulation of that fluid, was previously proved by Mr. BAUER, who filled glass tubes with blood recently drawn, and tying them over with bladder, inverted them. At first there was no appearance of gas upon the surface, but as the blood coagulated, it was separated, and in the course of 24 hours was found in considerable quantity.

Having ascertained not only the existence of gas in the blood, but that it is separated during the process of coagulation, I was most anxious to discover whether, as in vegetables, the gas,

* See Annales de Chimie, Tom. XIII.

thus let loose, pervaded the surrounding fluid into which it is propelled, in any particular manner. With a view to determine this point, I wounded the skin of my arm with the point of a lancet, so as to draw a drop of blood, which was received into a watch glass in a fluid state, and placed in the field of the microscope. The eye was then kept constantly fixed upon it, to watch the changes that might take place. The first thing that happened, was the formation of a film upon the surface, that part beginning to coagulate sooner than the rest. In about five minutes, something was seen to be disengaged in different parts of the coagulum, beginning to show itself where the greatest number of globules were collected; and from thence passing in every direction with considerable rapidity through the serum, but not at all interfering with the globules themselves, which had all discharged their colouring matter; wherever this extricated matter was carried, a net-work immediately formed, anastomosing with itself on every side, through every part of the coagulum. When the parts became dry, the appearance of a net-work remained unaltered. In some instances, bubbles were seen to burst through the upper surface of the coagulum: this, however, did not prevent the ramifications that have been described from taking place. The annexed Plates give the exact representation of the appearance the blood taken from my arm put on, when it coagulated and became dry, as shown in the field of the microscope. [Pl. ix, x.]

If the blood is cold when it is exposed in the microscope, and there is a larger quantity of serum upon the glass, the net-work is only formed in those parts where clusters of globules are collected; and when the serum dries, it cracks, and spoils

the appearance. This happens sometimes several days after the formation of the net-work has taken place. When clear serum without any globules is put upon the glass, nothing is extricated, but when the serum is quite dry, it cracks, and the cracks may be mistaken for the net-work; but by comparing them with it, the difference is found to be obvious.

These facts which Mr. BAUER has enabled me to bring forward, appear to point out an important change the blood undergoes, after it is extravasated. When this happens in living animal bodies, from whatever cause, and in whatever circumstances it takes place, no difficulty remains in accounting for its afterwards becoming vascular, since all that is necessary for that purpose is the red blood being received into the channels of which this net-work is formed.

I shall not detain the Society with any farther observations in support of what I have advanced, satisfied that if the facts do not bear themselves out, it will be superfluous to load them with theoretical opinions.

I cannot conclude this Lecture, without paying a tribute to the President of the Society; not a tribute of praise, but a tribute of justice; for whenever general science, or any of its branches, are brought under his consideration, the zeal and exertion, which he shows upon all occasions, to promote the pursuits of individuals, exceeds whatever has been done by others, in this or any other country, and is above all praise.

Whatever Mr. BAUER has already done, and whatever he may hereafter bring to light, respecting the more minute parts of animal bodies, is entirely to be attributed to the President; for it is at his particular request, under his encouragement, and in compliance with his wishes, that Mr.

BAUER has put a restraint upon himself, and for a time laid aside the prosecution of the Anatomy of Vegetables, which from his early youth has been his favourite occupation, to assist in bringing to light appearances in the anatomy of animals, which, without his aid, must still have remained in obscurity.